Thermosyphon Flooding Limits in Reduced Gravity Environments

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Fission Power Systems have long been recognized as potential multi-kilowatt power solutions for lunar, Martian, and extended planetary surface missions. Current heat rejection technology associated with fission surface power systems has focused on titanium water thermosyphons embedded in carbon composite radiator panels. The thermosyphons, or wickless heat pipes, are used as a redundant and efficient way to spread the waste heat from the power conversion unit(s) over the radiator surface area where it can be rejected to space. It is well known that thermosyphon performance is reliant on gravitational forces to keep the evaporator wetted with the working fluid. One of the performance limits that can be encountered, if not understood, is the phenomenon of condenser flooding, otherwise known as evaporator dry out. This occurs when the gravity forces acting on the condensed fluid cannot overcome the shear forces created by the vapor escaping the evaporator throat. When this occurs, the heat transfer process is stalled and may not re-stabilize to effective levels without corrective control actions. The flooding limit in earth's gravity environment is well understood as experimentation is readily accessible, but when the environment and gravity change relative to other planetary bodies, experimentation becomes difficult. An innovative experiment was designed and flown on a parabolic flight campaign to achieve the Reduced Gravity Environments (RGE) needed to obtain empirical data for analysis. The test data is compared to current correlation models for validation and accuracy.

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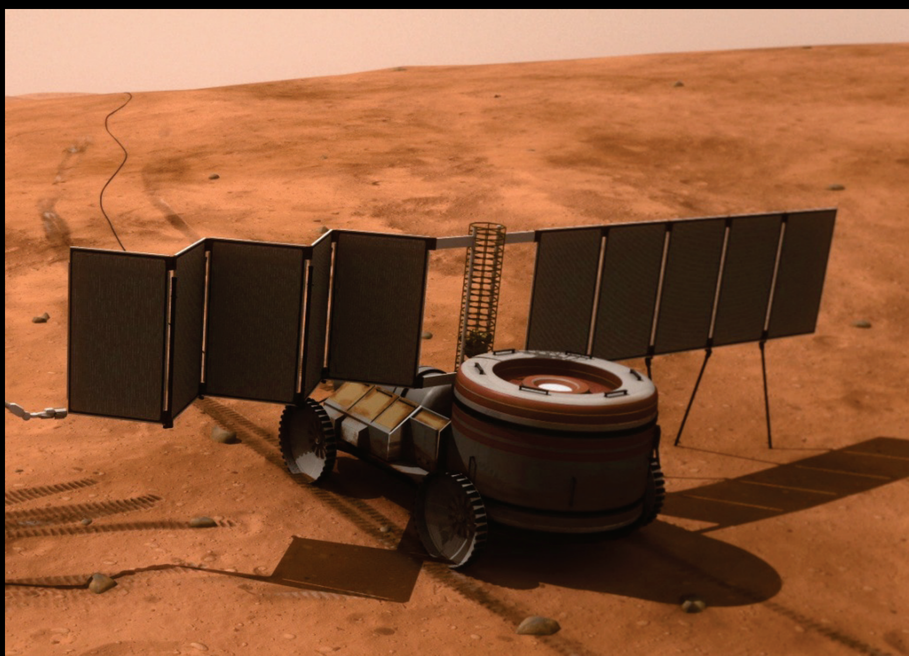
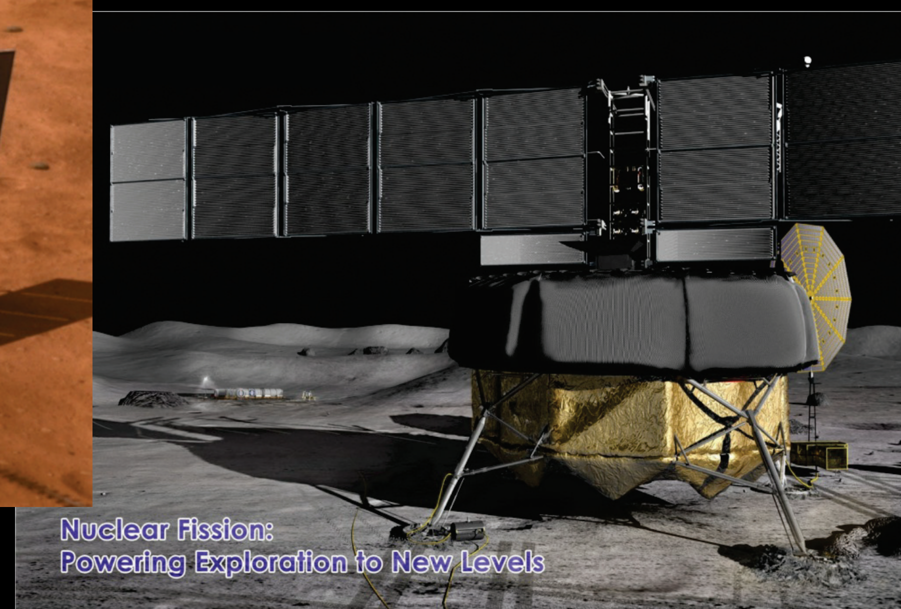
Planetary Application of Fission Power

- Lunar and Martian architecture teams identified Fission Power Systems (FPS) as a potential power source for use in human and robotic missions.
- FPS need to reject 70% of reactor heat.

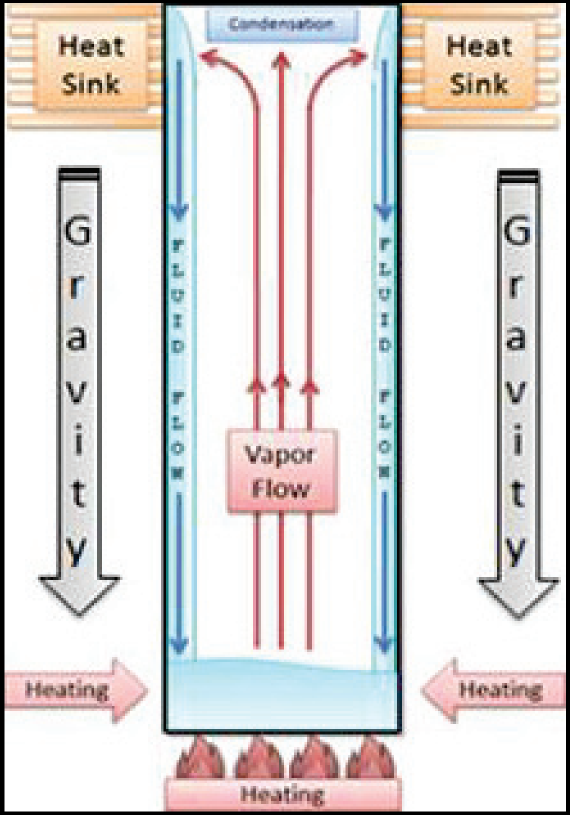


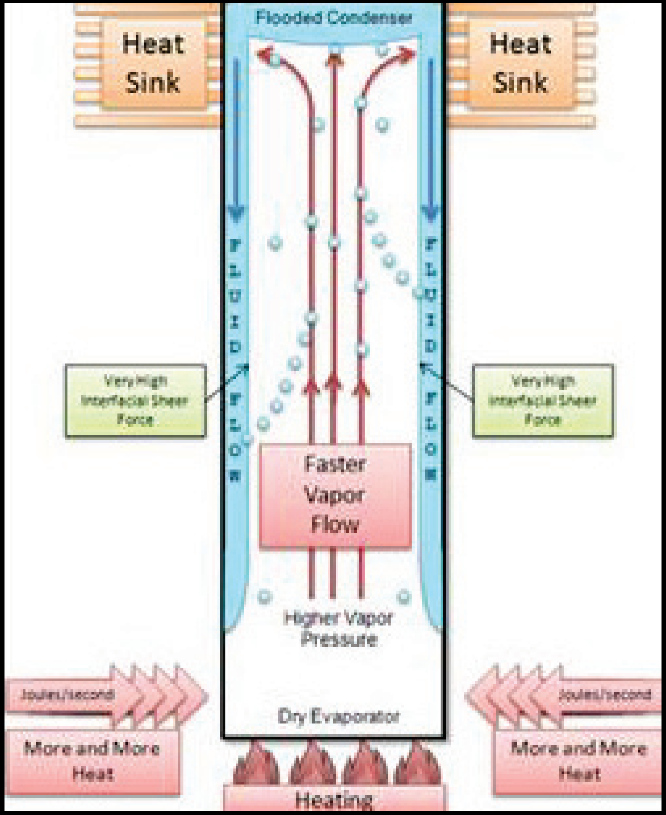


Full Scale Thermosyphon Radiator for Lunar or Mars Surface System

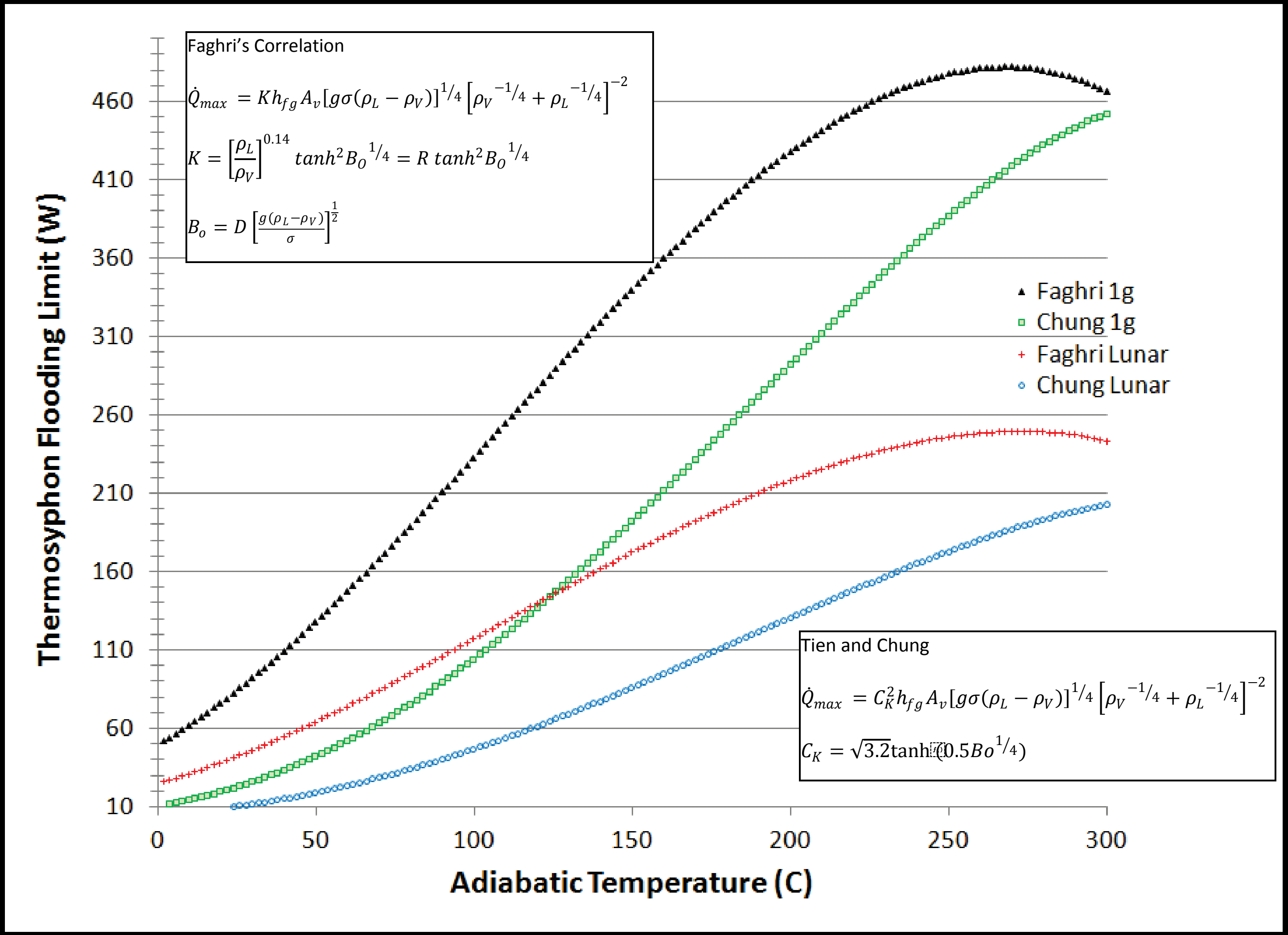
- Radiators using large L/D ratios are an effective way to spread and reject waste heat
- The reduced gravity of lunar and Martian environments directly effect the heat transfer limits of thermosyphons
- Understanding these limits requires testing in Reduced Gravity Environments (RGE)
- Parabolic Flights provide the opportunity to obtain RGE test data.

The Flooding Limit



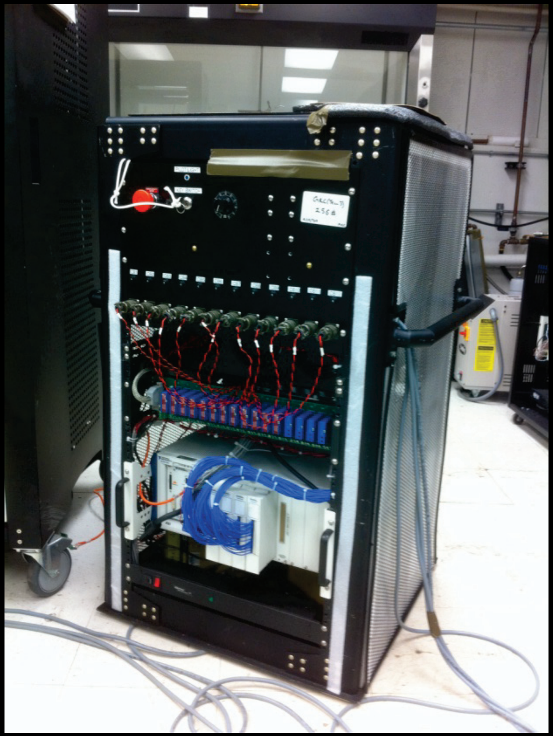


Correlation Predictions from Literature

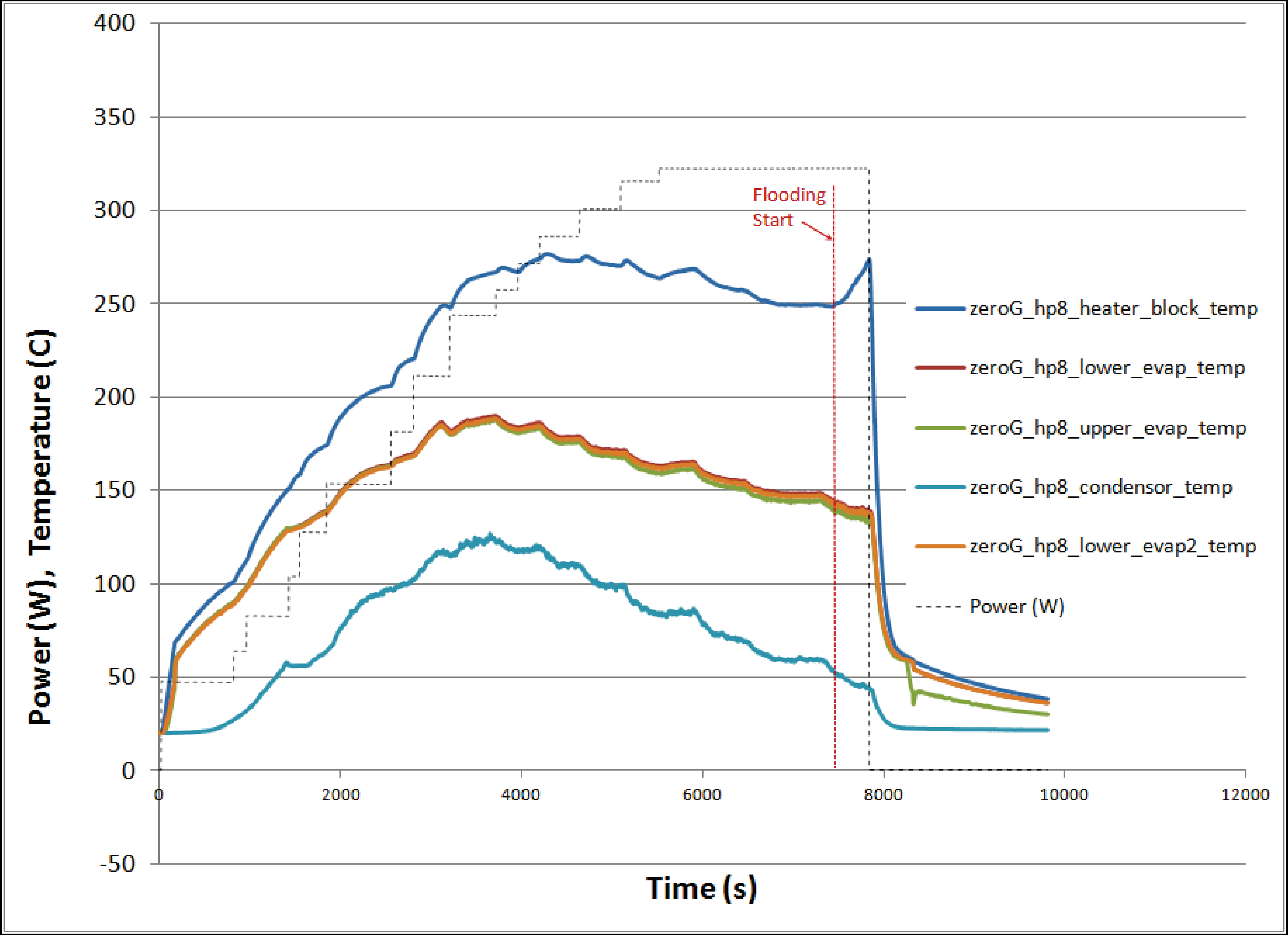


Experiment for laboratory and Flight Testing

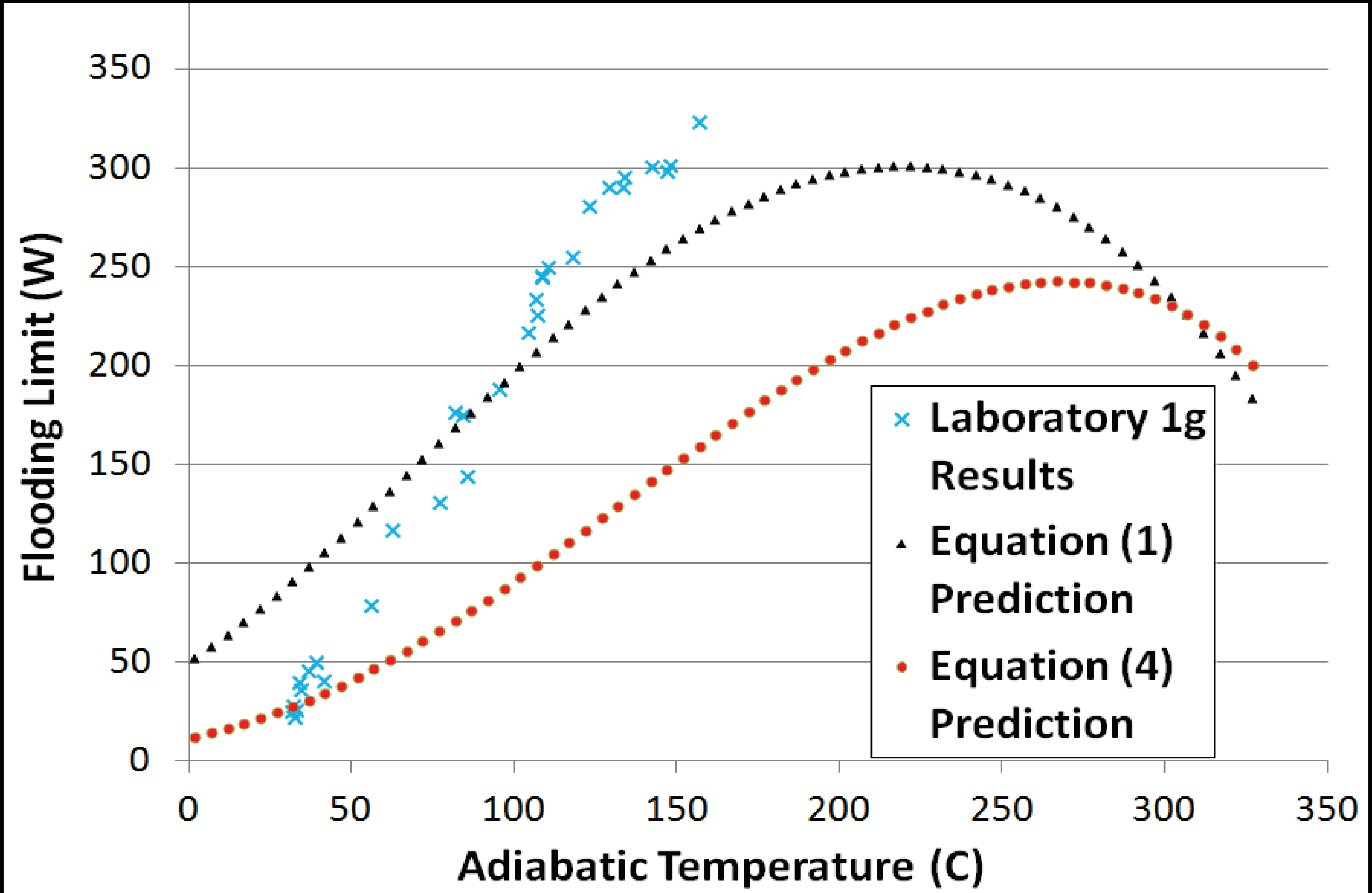
- Same hardware and test procedures used for 1-g and parabolic flight testing



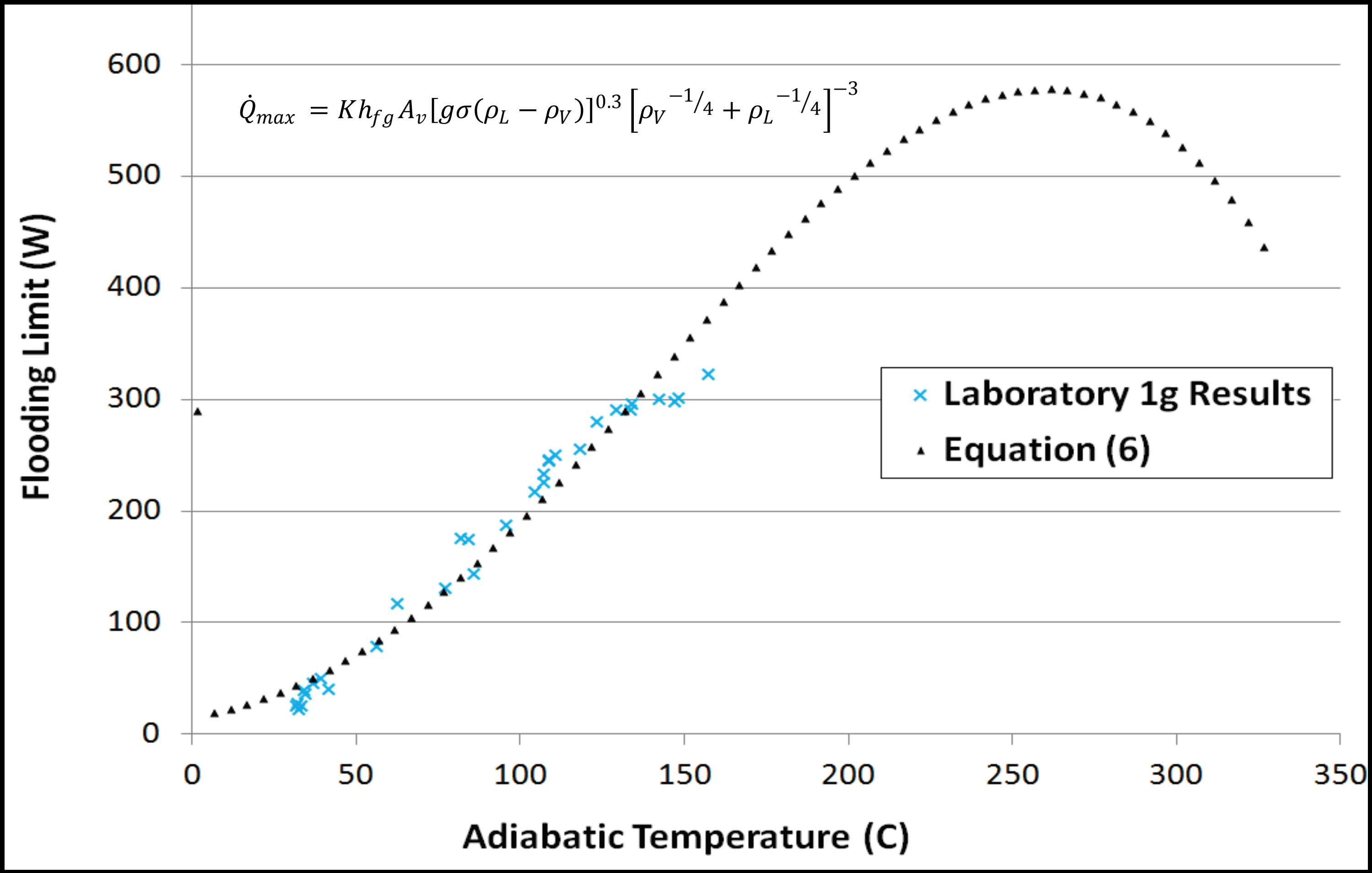
Establishing the Flooding Limit (1g)



1-g Flooding Limit Data from Laboratory Testing



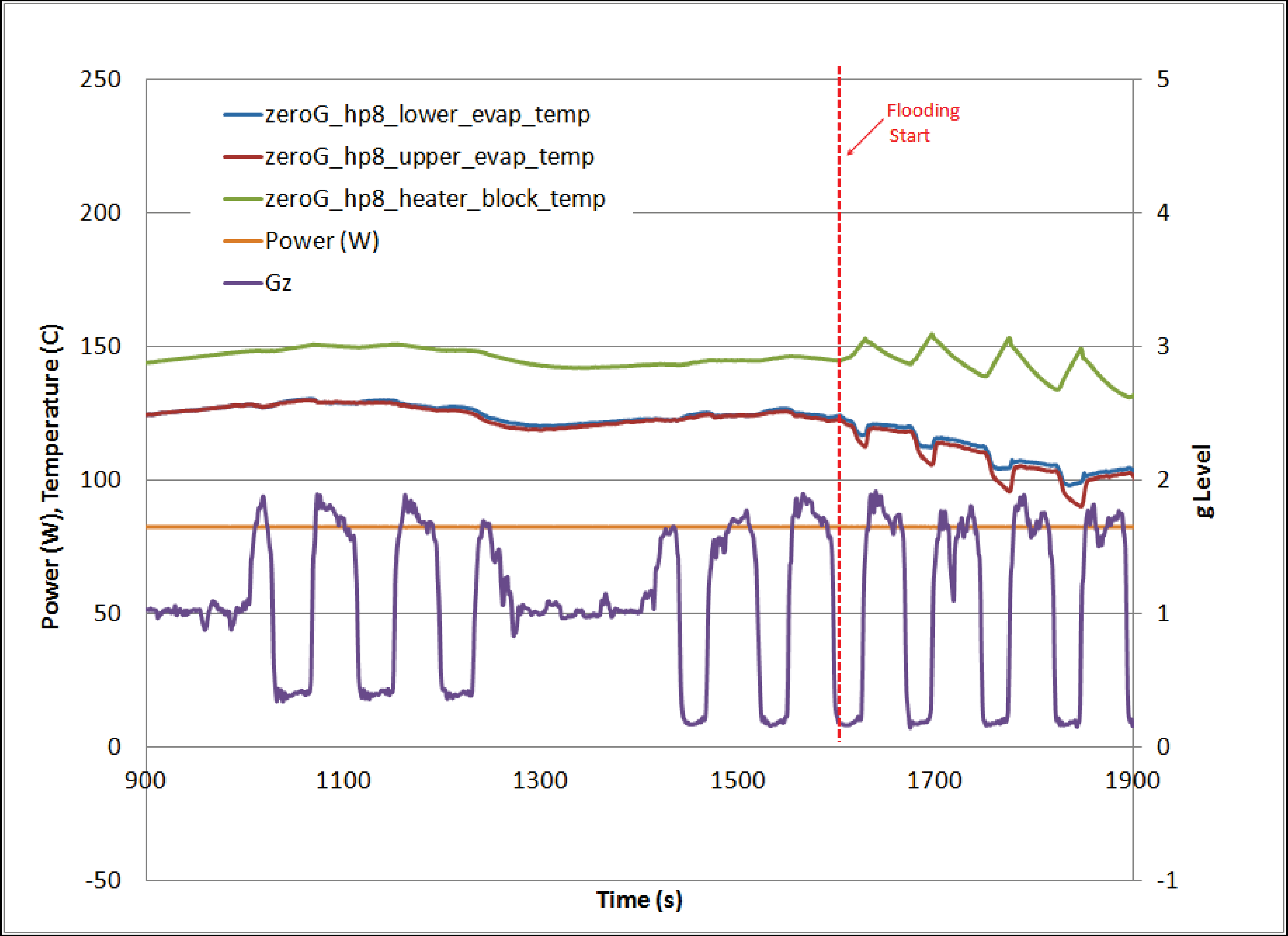
New Predictive Model based on 1-g Test Data



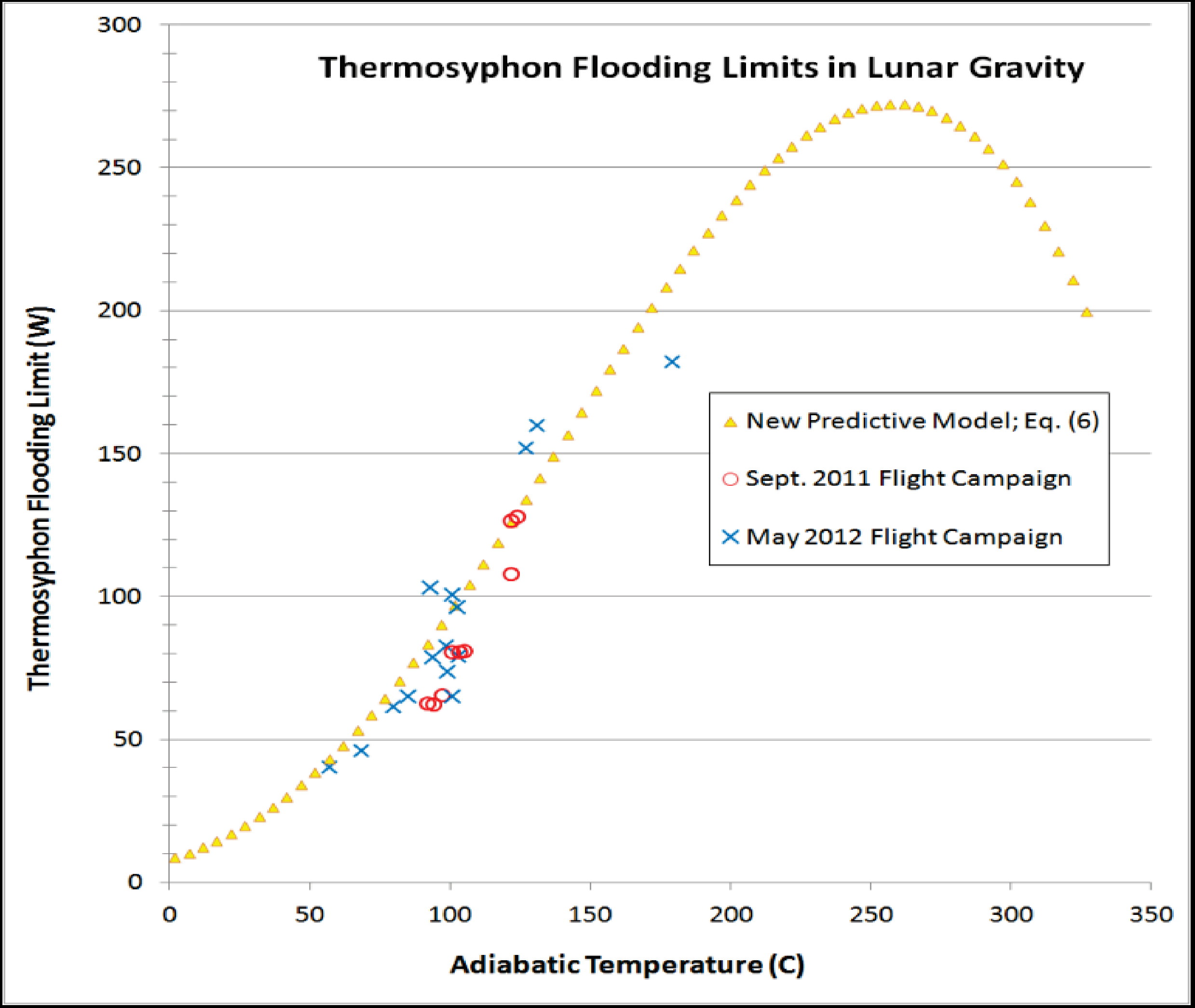
Parabolic Flights

- Sept. 2011
  - 40 parabolas per day
  - 12 Lunar, 3 Martian, 25 zero
  - 4 days totaling 160 parabolas
- May 2012
  - 15 lunar, 25 zero
  - 160 parabolas total

Parabolic Flight Data



Lunar Flight Test Results



Conclusions

- Thermosyphon flooding limits for large L/D ratios have been shown to differ from existing literature in 1-g and Reduced Gravity Environments (RGE).
- A first of a kind experiment flew in parabolic flight and acquired data to establish a new model for thermosyphon flooding in RGE.
- A new model was developed that matches test results for both 1-g and RGE, providing capabilities for future design predictions.